LESSON 14 – AIR TO GROUND ERROR MINIMIZATION
Those Eagle-driver prima donnas may think air-to-air is all there is, but that's because they've never experienced the thrill of a 45-pop delivery. If you've ever felt the "need for speed", low-level is where it's at!

Reading:
        11-F16 **Sec 5.6.6 (p. 134), Sec 5.7.8-5.7.8.6 (pp. 139-145)**
        F-4 Conventional Weapons Delivery Handout **Sec 3-3 (pp. 3-6 to 3-11)**
Problems/Questions:
        Work on Problem Set 2
Objectives:
        14-1   Understand the 6 factors that can cause manual bombing errors.
        14-2   Understand the 3 main sources of computed bombing errors.

Last Time: Surface-to-air threats
                    Getting to the target
                    Three types of dumb bomb deliveries

Today: Bombing Theory
                        Parameters and angles
                        Errors and their results

Bombing using manual deliveries of dumb bombs is the most primitive form of attacking the mud from the sky known to man. Ever since pilots in WWI first took hand-held bombs up with them and tossed them overboard at the enemy, the theory behind dumb bomb delivery has stayed almost exactly the same.

With the advent of modern precision-guided munitions (PGMs), attacking the mud has become much more precise. No longer do pilots have to hit exact parameters at exactly the right time to shack the target. Small errors in parameters can be corrected after release, in strong contrast to the manual delivery of dumb bombs. However, they still have to be able to hit less-exact parameters in order to allow their weapon to have the proper energy to make it to the target.

Even the Viper, with its extremely limited PGM capability, does not deliver its dumb bombs via manual delivery; they have sophisticated computers that continuously compute where the bomb is going to go at any particular instant, and display that information to the pilot in an intuitively obvious display on the HUD.

==Show Wiz's bomb delivery videos from Iraq==

So, with the advent of modern displays and PGMs, why am I going to have you learn about manual delivery of dumb bombs? Again, the thesis of this course is that physics drives tactics. The tactical approach of getting your jet to the right point in space in order to put your ordnance on target is the same physical problem, regardless of whether you're dropping Mk 82s off a Phantom or GBU-28s off a Strike Eagle. Successful weapons deliveries all boil down to energy considerations, its just that the energy basket into which you have to place the weapon is considerably larger for PGMs. If you can hit the parameters needed to obtain a shack with a manual dive bomb, you can easily hit PGM parameters. Also, an understanding of the basic physics behind manual deliveries will enhance your ability to understand the more complicated factors behind PGM operations. Bottom line: if you understand the basics and can perform more difficult tasks, you'll be better at using the more user-friendly systems you'll see in combat.

I said that all bombing involved releasing the bomb so that it had the right energy to end up exactly on the target. When delivering dumb bombs, you have to give the bomb exactly the right energy at release, because there's no opportunity to change that energy once the bomb has left the aircraft. The only difference between a manual delivery and a computer assisted delivery is that the parameters required to get to that exact energy state must be calculated prior to stepping out to the jet for a manual delivery. You've got to do a lot of pre-flight planning, starting with the target and working backwards, to figure out where your jet has to be at weapons release.

==Show bombing table overhead==

Notice that in the table there are three parameters you have to hit: release velocity, release airspeed, and release dive angle. In order for you to shack the target, you have to hit all three of these parameters at the exact instant that your pipper lines up with the target. Sound hard? It's even harder than it appears. Not explicitly stated in these tables are the assumptions that you're flying your jet at 1 G with no yaw or bank! And we won't even begin to discuss the effects of wind on the bomb once it leaves the aircraft! Manual bombing is about as precise a physical task as anyone is ever asked to do. If you bomb well manually, you know that you can fly a jet with the best of them.

On the bombing tables, there was a column labeled "sight setting". What did that mean? In the Phantom, we had a very rudimentary HUD, head's up display, and a rudimentary bombing computer that would move a basic pipper around to show where the bomb was going to go, much like the "death dot" you saw in the Viper deliveries I showed earlier. It wasn't anywhere near as sophisticated as that one. In fact, it looked a lot like this:
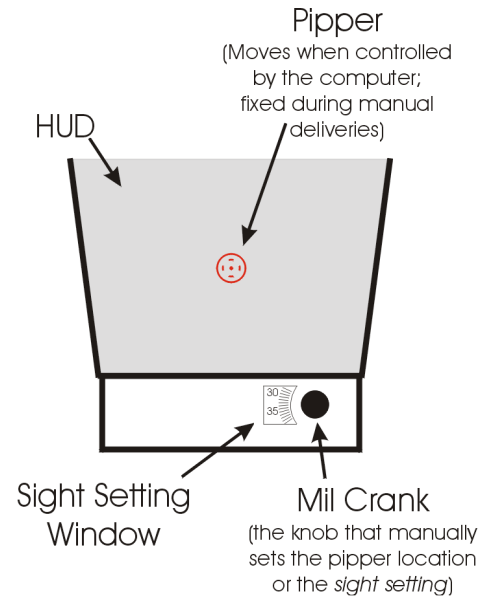
When you decide what parameters you want to use for the delivery (dive angle, airspeed, and release altitude), you read off the sight setting from the table. There are a number of other parameters you also get from the table, such as bomb range, slant range, and bomb time of flight. This diagram explains the relationship between these values.
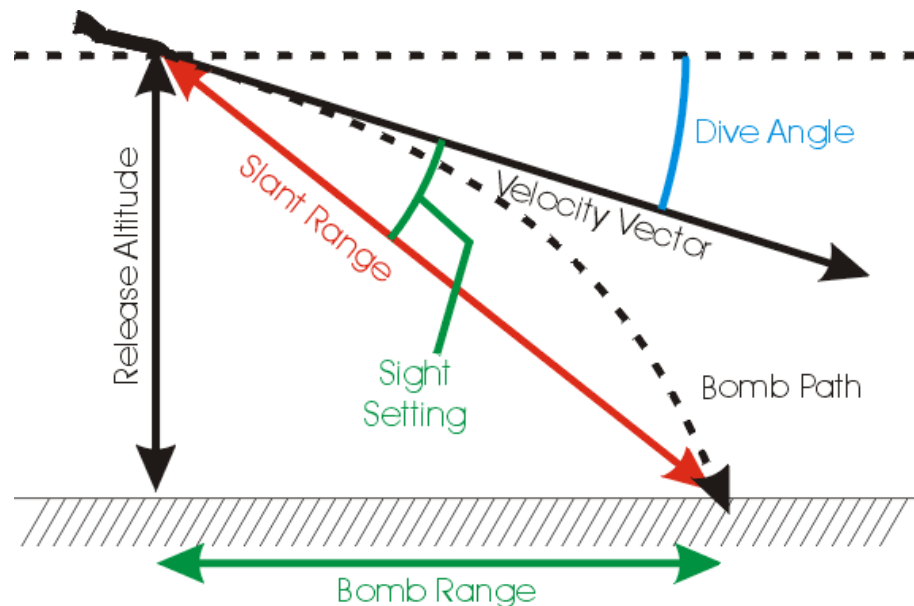
The above figure actually has a couple of approximations in it related to the sight setting. In that figure, the sight setting is measured from the velocity vector. That's not exactly true. Let's look at the real relationship that sets the sight setting.

The sight setting is a vector that is fixed to the airframe of the jet. The velocity vector *isn't* fixed to the jet. Does this make sense? Sure it does. Remember that the angle of attack (AOA) is the angle between the chord line and the velocity vector. The chord line was fixed to the airframe, while

the velocity vector wasn't. Instead of basing the sight setting on the chord line, it is instead based on another airframe-fixed vector, the boresight line. You can imagine the boresight as being a vector parallel to the aircraft's longitudinal axis that passes through the HUD. For the purposes of this discussion, we'll define the AOA as the angle between the velocity vector and the boresight line. This diagram shows the angles necessary to understand bomb geometry.
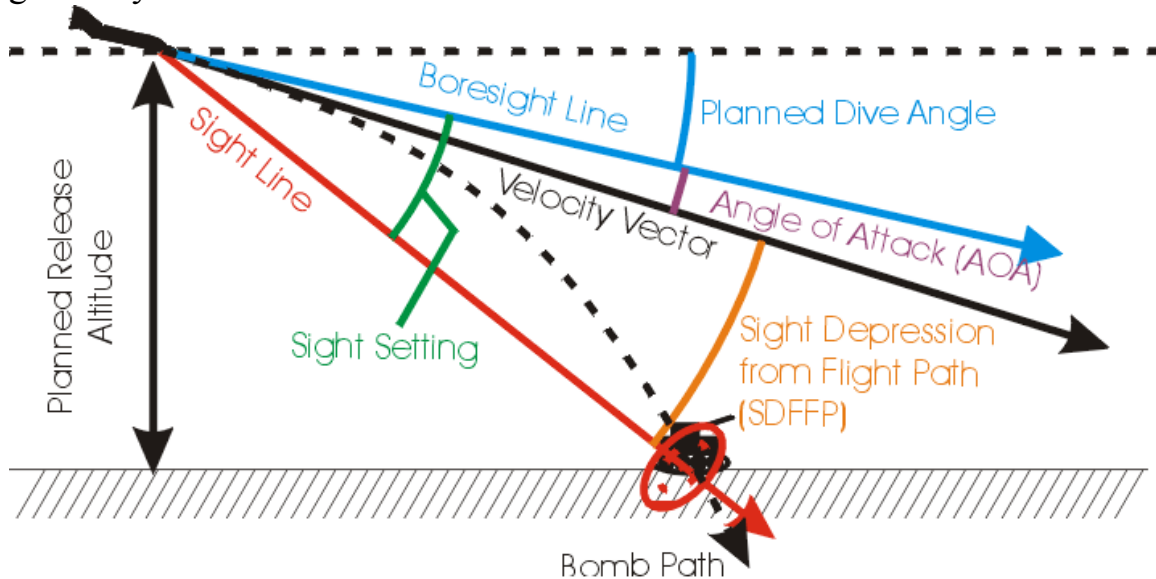
I've emphasized that the only way to shack the target is to make sure that you hit your dive angle, airspeed, and altitude while flying at 1 G with zero bank or yaw *exactly* at the same time that your pipper moves across the target. Let's see what happens if you don't meet all of you parameters. We'll look at parameter errors one at a time, and assume that all other parameters are met. This should help us isolate the error associated with the parameter we're missing.

Let's look at a level delivery first. If we're on altitude and airspeed, and flying exactly level, then when the pipper hits the target we can release and get a shack.

Show "Level Bombing On Altitude.avi"

Notice that the pipper starts out short of the target and then eventually appears to run across the target.

What happens if we're a bit high or low?

Show "Level High Delivery.avi" and "Level Low Delivery.avi"

Would you characterize flying low as being too aggressive (being a "tiger") or too wimpy? You're releasing closer to the ground, so you're being a little more aggressive. Let's keep track of "tiger" errors and "wimp" errors and see if there's a trend. So far, we've got:

Parameter	Error	Tiger or Wimp	Miss Direction
Altitude	High	Wimp	Short
	Low	Tiger	Long

The next error we'll look at is an error in dive angle.

Show "Steep Shallow.avi"

Which error was being too aggressive? Steep, right? Let's add to our table:

Parameter	Error	Tiger or Wimp	Miss Direction
Altitude	High	Wimp	Short
	Low	Tiger	Long
Dive Angle	Shallow	Wimp	Short
	Steep	Tiger	Long

Looks like there's a trend!

The next error will be in velocity. I don't have a video for this one, but you can probably figure out what will happen. If we're way too fast, where do you think the bomb will fall? Longer than planned, right? Too slow is similarly intuitive. Which seems more aggressive? Too fast, of course.

The last long/short error we'll look at is improper G loading. This is a fairly common error, as when you're coming down final you realize that you're not going to have the pipper on target as you hit your release altitude. Many times, novice bombers either pull the pipper up to the target (too many G's) or push the pipper down ("bunt"). When you give a quick push or pull on the stick, the only thing you really change quickly is the AOA. The jet

doesn't have time to change its velocity very much. Let's look at the next animation to see what changing only the AOA will do to the bomb.

Show "Bunt Pull.avi"

So, which seems more aggressive? Pulling too many G's gets you away from the ground more quickly, so we'll consider that the wimpy way, while bunting pushes aggressively toward the ground. Let's finish out our table of errors and make some conclusions.

Parameter	Error	Tiger or Wimp	Miss Direction
Altitude	High	Wimp	Short
	Low	Tiger	Long
Dive Angle	Shallow	Wimp	Short
	Steep	Tiger	Long
Airspeed	Slow	Wimp	Short
	Fast	Tiger	Long
G loading	Pull	Wimp	Short
	Bunt	Tiger	Long

It's pretty clear that <u>tiger errors give long bombs, while wimp errors give short bombs</u>.

The last two errors are improper bank angle and improper yaw angle. We won't discuss these errors in this course other than to say that their results are side-to-side errors rather than long/short errors.